

nervous energy through the phrenic will diminish and lead to movements of the vocal cord in which the excursions will be equal to, and not greater than, those of the vocal cord on the opposite or normal side?

Another question also requires an answer: When the vocal cord is moving normally through nervous impulses conveyed to it through the phrenic, will the patient be able to phonate? This is the question asked by Sir Frederick Mott. The answer can hardly be decided by experiment on the monkey: operation on man will give the reply. This will be the decisive experiment.

The conclusion, therefore, appears to be, that for the cure of recurrent laryngeal palsy and the attainment of normal movement of the vocal cord in tranquil respiration, anastomosis with the vagus or the descendens noni must be rejected, and some form of anastomosis should be carried out with the trunk or with one of the roots of the phrenic nerve.

The Medical Research Council has defrayed the expenses of this research, and given me every possible assistance at the National Research Institute.

## THE EFFECT OF DIET ON THE DEVELOPMENT AND EXTENSION OF CARIES IN THE TEETH OF CHILDREN.\*

(Preliminary Note.)

BY

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### INTRODUCTION.

It has been found by May Mellanby<sup>1</sup> in her experimental work on puppies, first published in 1918, that the structure of the teeth and their arrangement in the jaws are controlled by the diet and environment to which the animals are subjected during the period of development of their teeth. Some dietetic factors tend to help, and others to hinder, the formation of well calcified, evenly arranged teeth. In the former group are to be found substances rich in a vitamin closely allied, both as regards distribution and properties, to vitamin A. This group of substances includes cod-liver oil, animal fats (except lard), milk, and yolk of egg. Among those foods which lead to the development of badly formed teeth, cereals, and particularly oatmeal, occupy a prominent position. Thus the total influence of a mixed diet on the structure and the arrangement of the teeth in the jaws of puppies is the outcome of a battle between different dietetic influences.

In addition to the influence of diet, May Mellanby<sup>2</sup> has also shown that exposure of the animal to either sunlight or other sources of ultra-violet radiation has, under some conditions, an important influence on tooth formation. It is probable that the effect of these radiations is to make active the calcifying vitamin stored in the body. In fact, the interaction of the dietetic and environmental influences on tooth formation is certainly very close.

Two questions arise from the experimental work on the factors influencing the formation of puppies' teeth: first, Do the same factors control the formation of the teeth of human beings? and secondly, What relation have these facts to dental caries in man?

With regard to the first question, it is not yet possible to state that the results are applicable to man, in spite of the fact that the experimental work was published some years ago. There seems, however, some justification for believing that they are. It may be said also that if the results of this experimental work can be extended to man, a partial answer to the second question is supplied, for if teeth perfectly formed and well arranged in the jaws can be produced in children by feeding them along the lines suggested by the animal experiments, then such teeth will be less liable to caries than if they were imperfectly formed.

Although such a relationship is obvious to some, yet the idea is not generally accepted by dental authorities, because of the supposed fact that children's teeth are in general

well formed and yet very liable to become carious. May Mellanby,<sup>3</sup> however, found, when examining a large number of children's teeth under the microscope, that on the whole the more perfectly formed teeth, as evidenced by microscopical examination, were the least carious. There were, however, exceptions to this rule, for out of 302 teeth examined microscopically 11 were carious and yet well formed, while 13 were free from caries although of defective structure. Closer examination revealed that when teeth were well formed and carious any secondary dentine present was usually poorly calcified; and, on the contrary, badly formed teeth free from caries, or in which caries had been arrested, generally had some well formed secondary dentine. It appeared, in fact, that although the formation of the original enamel and dentine was as a rule a good indication of the susceptibility of a tooth to caries, the presence and structure of secondary dentine indicated a second line of defence dependent on resistance set up in the body and particularly in the tooth itself.

These data, obtained by examination of deciduous teeth of children, were further correlated with some experimental results which showed in a few cases that good secondary dentine was formed in puppies' teeth on a "good" diet, and imperfect secondary dentine when they were on a "defective" diet. Thus it appeared probable that in children also "good" diets might contribute to the arrest of decay. On the contrary, diets compatible with the formation of bad enamel and dentine might be expected to offer less resistance to the initiation and spread of caries. It may be noted here that the resistance of the puppies to infective processes generally was found to be closely dependent on their diet—a "good" diet affording them great resistance, and a "defective" diet rendering them more susceptible. Reference must also be made to the claim of McCollum, Simmonds, Kinney, and Grieves<sup>4</sup> and Howe<sup>5</sup> that "caries-like" lesions can be produced in rats and guinea-pigs by diets defective in certain respects.

### OBJECT AND CONDITIONS OF INVESTIGATION.

It is evident that the previous experimental work suggested most strongly that dental caries in human beings would be influenced by the small but specific differences in diet above mentioned. It appeared necessary, therefore, to investigate this matter, because corroboration of the animal results and their extension in man to the problem of caries would, if forthcoming, raise this subject from a position of academic interest to one of immediate human utility.

The children under observation were in an institution during the period of the investigation, and their diet and environment generally were under the close supervision of one of us (C. L. P.), by whom the improvement in the health of the children was carefully watched.

Three groups of children were taken. One set (nine in number) were placed on diet (diet A) which included cod-liver oil, milk, and eggs, but no oatmeal. On the basis of the investigations referred to above, this diet, which has a potent effect in bringing about calcification, might be expected to increase the resistance of the body, and especially the teeth, to bacterial infection. The next group consisted of ten patients, who received a diet (diet B) similar on the whole to diet A—the chief differences being that it included oatmeal, very little egg, and less milk than diet A, and no cod-liver oil. The third group consisted of thirteen children chosen from patients on the ordinary hospital diet (diet C). They were selected so as to be comparable with the first two groups in age, duration of institutional treatment, etc.

The diets eaten by the three groups are indicated below, but naturally the quantities varied to some extent with the age of the child.

It will be noticed that diet B, which contains more cereal, including oatmeal, and less calcium and vitamin A, is otherwise not very different from the ordinary hospital diet (diet C), which holds an intermediate position—so far as power to stimulate calcification in puppies is concerned—between diets B and A.

The effect of the three diets on the patients was very carefully watched, and as far as could be observed there was no difference in the improvement of the general health

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TABLE I.—Daily Diet.

Diet.	A.	B.	C. (Hospital Diet.)
Milk ... ..	2 to 1½ pints	¾ to 1 pint	1½ pints
Bread ... ..	2 to ½ oz.	5 oz.	<i>Ad lib.</i>
Fat ... ..	1 oz. (butter)	1 oz. (margarine except towards end)	1 oz. (margarine except towards end).
Sugar (including cooking)	1½ oz.	3 oz.	1½ oz. and jam, etc.
Oatmeal, groats or gruel	—	2 to 4 oz.	Occasionally.
Rice, tapioca, etc.	½ oz.	½ oz.	½ oz.
Meat (cooked) ...	1½ oz.	1½ oz.	2½ oz.
Potatoes ... ..	2 oz.	4 oz.	4 oz.
Other vegetables	2 oz.	½ oz.	½ oz.
Cocoa ... ..	Made with milk	Made with water	Made with milk.
Egg ... ..	1	Very little	Sometimes.
Fruit, etc. ... ..	½ orange, or ½ tomato, or swede juice, 1 or 2 dr.	As in Diet A	As in Diet A.
Cod-liver oil ...	3 to 6 dr.	—	2 to 3 dr.

in the three groups. The condition of the mouth and teeth of each child was charted at the beginning of the dietary and also after some months, the period varying slightly in different cases. The difficulties of correctly recording all the findings are obvious, but we have tried to retain the same criteria throughout.

**Hypoplasia.**—The general condition of the teeth as regards hypoplasia obvious to the naked eye was noted. A special standard (based on the observations mentioned above) was adopted, and as far as possible used, throughout the investigations.

**Caries.**—An attempt was made to record the position, extent, and degree of softness and hardness of each carious point in the individual teeth. After periods which varied in the three groups from an average of seven and a half to eight months the teeth were again examined and the results charted. The number of teeth in which new carious areas had occurred since the first inspection and the number of teeth previously carious in which the caries had increased were noted. In addition, an attempt was made to record the amount of hardening or softening of the carious areas. Radiograms were taken at intervals, for it was thought possible that there might be some alterations in the structure and development of the bone surrounding the teeth, of a similar nature to that observed by May Mellanby in puppies.

**Histology.**—In most cases at the beginning and also after some months of the dietary one or more carious teeth were extracted, mounted in balsam, and ground down so that a microscopic examination could be made. By this means the detailed structure of some of the teeth can be compared with that observed macroscopically. It was hoped also from these sections to get an indication as to whether the diet had had any action on the carious process—such, for instance, as arresting it. This question will be dealt with when the investigation is more complete.

**Ultra-violet Light: Saliva.**—The action of ultra-violet light together with the different diets is being investigated, but the results will not be referred to in this preliminary paper. C. Lee Pattison is estimating the calcium content and hydrogen-ion concentration of the saliva of these patients. This will also be discussed in a separate publication.

#### RESULTS.

Before recording the results obtained the following points should be noted:

1. Children were selected for the three groups so that their home environment and diets from birth to admission to hospital were as nearly alike as possible—for example, particulars of the previous diet were obtained from the parents, and, although the value of these data is not great, efforts were made to have the groups as comparable as possible in this respect. In most cases the conditions of the homes were known from the personal observations of one of us (C. L. P.).

2. The average length of time during which patients were on the ordinary hospital diet, before the first inspection of their teeth, was, in months: Group A, 7.5; Group B, 8.5; Group C, 8.5.

3. The average age of the patients at the beginning of the experiment was, in years: Group A, 7.5; Group B, 7.5; Group C, 7.1.

4. The average period covered by the investigations was, in months: Group A, 7.5; Group B, 7.5; Group C, 8.

5. The average amount of dental hypoplasia observed by the naked eye was practically the same in the three groups A, B, and C.

6. The average number of carious teeth in each child before commencing the diets was: Group A, 6.25; Group B, 6.125; Group C, 7.

TABLE II.—Summary of Investigation and Results.

	A.	B.	C.
Number of patients in each group ... ..	9	10	13
Average time between admission and first inspection (months)	7.5	8.5	8.5
Average age at which diet started (years) ...	7.5	7.5	7.08
Average period covered by the investigation (months)	7.5	7.5	8.0
Average number of erupted teeth per child at first inspection	18.75	19.25	21.0
Average number of carious teeth per child at first inspection	6.5	6.125	7.0
<b>Extension of Caries.</b>			
Average number of erupted teeth per child at last inspection	17.75	18.0	20.5
Actual number of new teeth becoming carious between inspections	6.0	28.0	20.0
Average number of new teeth per child becoming carious	0.65	2.8	1.54
Number of teeth already carious in which caries increased	7.0	23.0	18.0
Average number of teeth per child in which caries increased	0.75	2.3	1.4
Total number of teeth showing new or increased caries	13.0	51.0	38.0
Average number of teeth per child with new or increased caries	1.4	5.1	2.9
Total number of carious teeth in which hardening has occurred	14.0	7.0	13.0
Softening has occurred in ... ..	0	4.0	1.0

It will be noted that the average age of the child, the period of investigation, and the dental condition before the first inspection were practically identical—in fact, the only obvious variation in the three groups was in the diet the children received. It is therefore this factor which is probably responsible for the differences observed in the dental changes.

TABLE III.—Average number of teeth per child showing a spread of caries previously present and new carious areas, together with the main differences in the three diets.

Diet.	Main Difference in Diet.	Average No. of Teeth per Child in which Caries has Spread.
A.	Abundant calcifying vitamin and calcium; small amount of carbohydrate, not including oatmeal	1.4
B.	Less calcifying vitamin and calcium; much carbohydrates, including oatmeal	5.1
C.	Intermediate amount of vitamin A, calcium, and carbohydrates; some oatmeal	2.9

In other words, the tendency for caries to spread was greatest in children receiving diet B, least in those receiving diet A, and intermediate in those receiving diet C.

#### SUMMARY.

It has been found that when children are fed on a diet which has been shown (by May Mellanby) in the case of puppies to result in the formation of well calcified teeth, then the initiation and spread of caries takes place at a slower rate than in the case of similar children fed on diets not having such potent calcifying activity. The diet giving the best results, besides having the ordinary qualities of a normal diet, is rich both in calcium and the calcifying vitamin, and contains comparatively little cereal, none of which is in the form of oatmeal.

#### REFERENCES.

- <sup>1</sup> May Mellanby: *Lancet*, 1918; *Dental Record*, 1920; *British Dental Journal*, 1923, etc.
- <sup>2</sup> The same: *British Dental Journal*, May, 1924.
- <sup>3</sup> The same: *Ibid.*, January, 1923; *Proc. Roy. Soc. Med.*, vol. xvi, 1923.
- <sup>4</sup> McCollum, N. Simmonds, E. M. Kinney, C. J. Grieves: *Bull. Johns Hopkins Hospital*, No. 382, 1922, p. 202.
- <sup>5</sup> Howe: *Dental Cosmos*, 1920, lxii.